GREENING THE MIXTURE: AN EVALUATION OF THE DEPARTMENT OF DEFENSE'S ALTERNATIVE AVIATION FUEL STRATEGY

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Cost, consumption, and accessibility issues surrounding foreign petroleum have driven the Department of Defense to develop and publish an energy strategy founded on reduction, diversification, and affordability. Federal environmental mandates, geo-strategic security, technology and logistics further complicate the achievement of energy security objectives. Aviation fuel possesses the greatest leverage for change and accounts for the largest percentage of energy use by the US Armed Forces. The individual Services, particularly the US Air Force and US Navy, have grappled with implementing coherent and attainable aviation fuel strategies over the near-, mid-, and long-term. Presented in this thesis are an overview of DoD strategy requirements, a history of Air and Naval alternative aviation fuel efforts over the past 15 years, assessments of the Services' and DoD's strategies, and recommendations for attaining stated objectives in light of the challenges of availability, suitability, and affordability

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The opinions and conclusions expressed herein are those of the student author and do not necessarily represent the views of the U.S. Army Command and General Staff College or any other governmental agency. (References to this study should include the foregoing statement.)

ABSTRACT

GREENING THE MIXTURE: AN EVALUATION OF THE DEPARTMENT OF DEFENSE'S ALTERNATIVE AVIATION FUEL STRATEGY, by Maj Joseph McKenna, 70 pages.

Cost, consumption, and accessibility issues surrounding foreign petroleum have driven the Department of Defense to develop and publish an energy strategy founded on reduction, diversification, and affordability. Federal environmental mandates, geo-strategic security, technology and logistics further complicate the achievement of energy security objectives. Aviation fuel possesses the greatest leverage for change and accounts for the largest percentage of energy use by the US Armed Forces. The individual Services, particularly the US Air Force and US Navy, have grappled with implementing coherent and attainable aviation fuel strategies over the near-, mid-, and long-term. Presented in this thesis are an overview of DoD strategy requirements, a history of Air and Naval alternative aviation fuel efforts over the past 15 years, assessments of the Services' and DoD's strategies, and recommendations for attaining stated objectives in light of the challenges of availability, suitability, and affordability.

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Any shortcomings or errors in this paper are mine alone.

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ACRONYMS

BPD	Barrels per day
CBTL	Coal and Biomass to Liquid
CCS	Carbon Dioxide Capture and Sequestration
CTL	Coal to Liquid
DARPA	Defense Advanced Research Projects Agency
DLA	Defense Logistics Agency
DoD	Department of Defense
EISA	Energy Independence and Security Act
FT	Fischer-Tropsch
FY	Fiscal Year
GHG	Greenhouse Gas
HRJ	Hydrotreated Renewable Jet
JP	Jet Propellant
LUC	Land-use-change
MIT	Massachusetts Institute of Technology
NDAA	National Defense Authorization Act
NSS	National Security Strategy
QDR	Quadrennial Defense Review
US	United States
USAF	United States Air Force
USN	United States Navy

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CHAPTER 1

INTRODUCTION

Aviation fuel accounts for the greatest percentage of energy costs for the United States (US) military. Billions of dollars are spent annually, with tactical systems and weapons platforms constituting 90 percent of the military's petroleum fuel demand.[1] National security and geopolitics complicate efforts to curb America's insatiable fuel demand and the formulation of effective national, defense and military energy strategies. Given the scale of consumption, the Air Force and Navy have focused on reducing energy demands in their strategies to meet larger defense and national energy objectives—with particular focus in the area of aviation fuel. This study will examine and evaluate the US' ability to meet its national, defense, and military goals regarding alternative aviation fuel, and provide recommendations on how the respective strategies can more effectively support the achievement of their objectives

Background

Reducing dependence on non-renewable energy sources has been a national policy objective for the past four decades. Still, the combined contextual elements of consumption, national security, operational uncertainty, force protection, and an environment of fiscal austerity have provided renewed justification for adopting a more aggressive strategy towards energy security. Nesting an ambitious approach to aviation fuel within these strategies presents the greatest leverage for savings, but poses complex challenges for the nation, DoD, and air forces.

Fuel consumption statistics are staggering. The DoD is the world's largest single industrial oil customer, consuming approximately barrels of oil daily.[2] Approximately half of this fuel is purchased within the United States.[3] In 2010, US military operations used more than five billion gallons of fuel at a cost of $13.2 billion dollars, representing a 255 percent increase over 1997 prices.[4] When oil spiked to $147 per barrel in 2008, the fuel bill reached $20 billion, or roughly 392 percent more than the 1997 price.[5]

More troubling, however, are the future use estimates. Global consumption is currently estimated at 86 million barrels of oil daily, and is expected to increase to 115-120 million barrels, or 75 percent, by the end of the decade.[6] The rise of Asian economies, such as those of China and India, have largely contributed to this increased forecast. Energy prices are further exacerbated by increased extraction costs, limited refinery expansion, and global supply speculation.[7]

National security and defense concerns also drive new attitudes towards fuel strategy. The *2010 National Security Strategy* (*NSS*) states that fossil fuel dependence "constrains our options, pollutes our environment, and will leave us vulnerable to energy supply disruptions and manipulation."[8] The Truman National Security Project further elaborated on price manipulation. According to its former COO, Jonathan Powers, each $5 increase in crude oil amounts to an additional $7.9B for Iran, $4.7 billion for Venezuela, and $18B for Russia.[9] The most recent *National Defense Strategy* acknowledged the relationship between the global economy, its requirement for ready access to energy resources, and increasing reliance on oil from areas of instability.[10]

Disruptions to oil flow have, and will continue, to provoke crises affecting global stability and security. Furthermore, the likelihood of oil-disrupting events--both natural and man-made--remains alarmingly high. Unpredictable weather pattern changes affecting North American oil refineries pose as great a threat as unresolved tensions among oil producing nations and their neighbors in the Eastern Hemisphere. For example, a closure of the Strait of Hormuz would affect approximately 17 million barrels of crude oil supply daily, representing 40 percent of all seaborne traded oil. A 2006 Government Accounting Office report estimated this event would cause oil prices to spike to $175 per barrel, causing devastation to the still recovering world economies.[11] Consequently, this event would have strategic implications for the United States in light of its dependence on non-renewable energy.

Recent logistics and sustainment operations in Iraq and Afghanistan highlighted the relationship between fuel security and force protection at the theater-strategic level. According to U.S. Transportation Command data, 1,100 attacks occurred against fuel convoys in 2010.[12] In 2007, this cost the U.S. Army 132 casualties in Iraq (.026/convoy) and 38 in Afghanistan (.034/convoy), representing approximately 12- and 35 percent of total FY07 US casualties in Iraq and Afghanistan, respectively.[13] The protection added to these convoys increased the effective purchase cost of fuel by a factor of 15.[14]

Operational fuel use represents the greatest proportion of fuel consumption for the United States Air Force (USAF) and Navy (USN) (see figure 1). The USAF accounts for approximately 64 percent of total aviation fuel costs within the DoD,[15] and 10 percent of all aviation fuel used in the United States.[16] Furthermore, the extent of petroleum use inherent in its respective missions exposes the Air Force and Navy to significant budgetary risk. A $10 per barrel increase in the price of oil results in an additional $610M dollar cost to the USAF annually.[17] The US Navy, the next largest DoD fuel consumer, saw a nearly five-fold increase in fuel costs during the 2008 oil price hike. Even a 35 percent savings in aircraft fuel would equal the combined DoD land vehicle and facility use.[18] The fiscal opportunities for reduced demand and alternative fuel investment are clear.

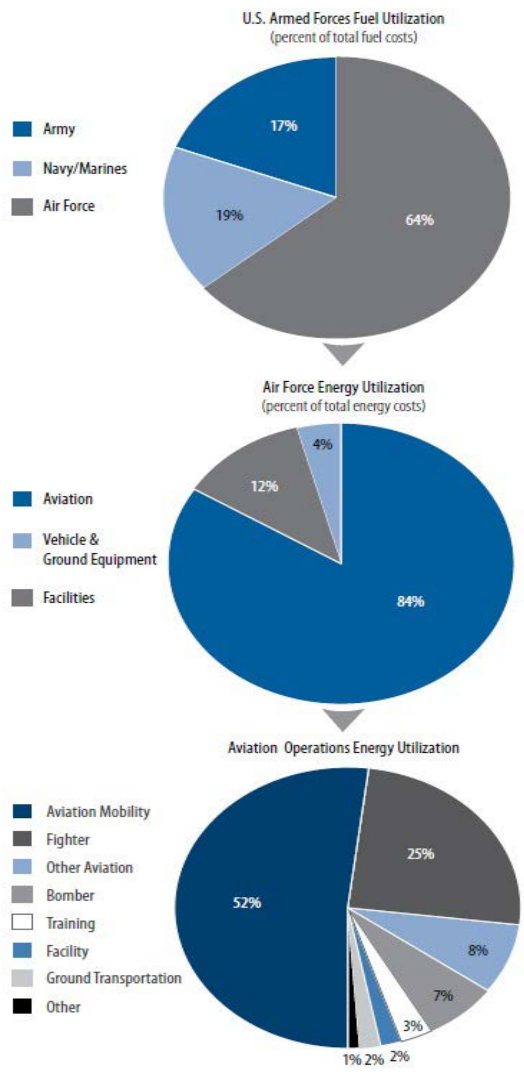

Figure 1. Energy Utilization Across Armed Services, 2009

Source: SAF/IE, *Air Force Energy Plan*, 2010, http://www.safie.hq.af.mil (accessed 24 April 2012), 2.

Contemporary energy legislation has changed the operating environment for the federal government. The Energy Independence and Security Act (EISA) of 2007 first associated the notion of energy security with the production of biofuels. It directed the Environmental Protection Agency Administrator to revise regulations to ensure that domestic transportation fuel sold or introduced into commerce, on an annual average basis, contain a specified volume of renewable fuel.[19] It further directed the Secretary of Energy to establish a grant program to encourage the production of advanced biofuels, and authorized appropriations for FY2008-FY2015. Executive Order 13514, titled *Federal Leadership In Environmental, Energy, And Economic Performance,* promoted a reduction in the federal government's vehicle fleet fossil fuels through the use of low greenhouse gas (GHG) emitting and alternative fuel vehicles, fleet vehicle optimization, and a two percent annual petroleum reduction through fiscal year 2020.[20]

Most recently, the Obama administration put forth *A Blueprint for a Secure Energy Future* that established a framework for reducing the nation's dependence on foreign oil.[21] The guidance also outlined a cooperative effort between the Secretaries of Agriculture, Energy, and Navy to accelerate the development of drop-in biofuels in order to meet Naval and commercial aviation and shipping demands. Acknowledging the challenges posed by weak economic conditions, initial technological risks, and petroleum industry inertia, the interagency initiative outlined objectives towards a cooperative approach to the construction or retrofit of multiple domestic drop-in biofuel plants and refineries. The goals of the initial three year, $510 million funding are to produce competitively priced military specification advanced biofuels, from geographically dispersed facilities, and with no significant impacts on agricultural commodities or food production.[22] Furthermore, the combined interagency investment must be offset by at least a one to one match from private industry.

Fuel consumption efforts have also impacted the federal government's largest consumer--the Department of Defense. Ever cognizant of the fuel price fluctuations and increased global presence, each military branch has attempted to reduce fuel consumption and seek cleaner, alternative energy sources to meet operational demands while deployed and in garrison. Though the Air Force and Navy have embarked on alternative aviation fuel research and development efforts since the mid-2000s, it was not until the fiscal year National Defense Authorization Act of 2009 that a designated entity was created within DoD to strengthen the energy security of US military operations.[23] The Office of the Assistant Secretary of Defense for Operational Energy Plans and Programs subsequently published a first-ever strategy to transform energy consumption during military operations. This strategy's primary objectives were based on efficiency, diversification, and greater capability at reduced cost.[24] Each service followed suit, producing individual strategies that codified previous efforts and incorporated larger defense goals into their respective operations. Other DoD entities, such as the Defense Advanced Research Projects Agency (DARPA) and the Defense Logistics Agency (DLA) –Energy, also embarked on aggressive projects to research and implement economically feasible aviation biofuels. The collision of technological hurdles, high-tempo global operations, limited federal fuel mandates, and recent budget sequestration effects present enormous challenges for the DoD to meet its strategic objectives for aviation fuel.

Primary and Secondary Research Questions

What is the Department of Defense near-, mid-, and long-term strategy towards aviation fuels? Secondary questions are:

1. What are the primary motivations behind traditional fuel reduction and implementation of alternative aviation fuel?

2. What are the current US policy, goals, and objectives regarding aviation fuels?

3. What do the US Air Force and Navy strategies have in common, what are their differences, and are they likely to be successful?

4. What are the challenges associated with the alternative fuel technologies from a technological, environmental, and cost perspective?

a. What are the differences in the various approaches to alternative fuels?

b. Do foreign and domestic alternative fuel industrial bases have the capacity to meet mid- and long-term defense strategies for aviation fuel?

5. What changes need to be adopted, both at the national, defense, and Service levels to improve the current aviation fuel strategy to meet stated goals?

Definitions

A brief glossary of key terms relevant to this study is listed below in order to assist the reader in understanding concepts and terms presented in this study. Terms and the subsequent discussions are derived from a variety of military and private industry sources.

Alternative Fuels. According to the Environmental Protection Agency Acts of 1992 and 2005, and EISA 2007 alternative fuels are the first of three types of non-petroleum liquid fuels. They are those transportation and mobility fuels that are not derived from traditional liquid petroleum including renewable and synthetic fuels.[25]

Carbon Dioxide Capture and Sequestration (CCS). The production of alternative fuel blends from coal sources produces twice the amount of greenhouse gasses than petroleum production, of which half is carbon dioxide.[26] There are two processes available that allow coal-derived alternative fuel production with carbon dioxide emissions less than or equal to traditional petroleum: capture and sequestration. Captured carbon dioxide from coal-to-liquid (CTL) or coal and biomass-to-liquid (CBTL) production could be readily injected into the earth during domestic oil recovery, a process in which between 30 and 40 million tons of carbon dioxide are currently extracted from natural reservoirs each year. Sequestration, a process through which carbon dioxide is injected into geological formations, is a viable solution in areas that lack proximity to oil basins.

Fischer-Tropsch (FT) Method. Invented in Germany by scientists Franz Fischer and Hans Tropsch during the 1920s, this process begins with gasification of feedstocks such as coal, natural gas, or biomass towards the production of alternative fuels. With adequate carbon capture or sequestration, FT-derived fuels burn cleaner than petroleum products; produce fewer particulates and no sulfur dioxide.[27] Furthermore, CBTL fuel produced in combination with carbon capture and sequestration could result in fuels with up to a 50 percent reduction in lifecycle GHG as compared to Jet A. FT 50/50 synthetic fuel blends have been certified for military and commercial aviation use.[28]

Hydrotreated Renewable Fuel. These fuels are produced by combining hydrogen with the oils found in algae, animal fats, or seed-bearing plants such as soybeans, jatropha, or camelina.[29]

Land-use-change (LUC) emissions. Biofuel creation results in changes to land use that could result in increased GHG emissions. The conversion of land for the farming of biomass-energy crops may result in atmospheric release of carbon dioxide. Factors affecting the amount of this release are the types of land and crops used. Surface mining of coal is not considered in LUC due to the insignificant emissions as compared to biofuel feedstocks.[30]

Operational Energy. Operational energy is defined as the "energy required for training, moving, and sustaining military forces and weapons platforms for military operations. The term includes energy used by tactical power systems and generators and weapons platforms."[31]

Renewable Fuels. Federal legislation identifies renewable fuels as those transportation and mobility fuels that are wholly derived from biomass or its decay products. These fuels can be used as a stand-alone fuel or blended with petroleum.[32]

Synthetic Fuels. Synthetic fuels are "liquid hydrocarbon fuels produced from coal, natural gas, or, increasingly, biomass."[33]

Assumptions

The majority of our national-level energy policy was developed and implemented prior to the onset of the existing global economic crisis. Therefore, it is assumed that significant budget reductions will likely reduce the scope of, but not obviate the need for, an aviation fuel strategy. Specifically, it is assumed that the 2011 Budget Control Act's

Sequestration measures will not impact the DoD budget. Similarly and despite a sagging global economy, fuel prices are assumed to remain constant or increase--further supporting the objectives of existing national and military energy strategies. Finally, it is assumed that incorporating a drop-in alternative fuel solution will mitigate significant logistical concerns at the operational and tactical level.

Limitations

The 2011 Budget Control Act's Sequestration provisions regarding defense spending make it difficult to forecast the DoD's ability to execute its energy strategy. While the DoD, Air Force, and Navy energy strategies each acknowledged fiscal constraints posed by high fuel costs, the fuel diversification efforts they presented are predicated on sufficient funding. Although the approved defense budget has not been released prior to the conduct of this study, it must be assumed that research and development for alternative fuels will be negatively impacted.

Based on the nature of the research topic and availability of secondary research data, no primary research was conducted during this study.

Scope

The focus of this thesis is the challenge of implementing an aviation fuel strategy that meets the desired DoD and individual service end-states. Energy Security and transformation applies to all facets of DoD operations. While solar, wind, and nuclear energy are viable areas for alternative energy research, this study will focus on petroleum-based fuel sources as the avenue with the most challenge and greatest leverage for change as they pertain to national and military strategies.

Therefore, the scope is limited to the study of aviation fuel diversification through emerging technology. This study begins with the examination of current US policy, goals, and objectives regarding aviation fuels. Next, comparative analyses of Air Force and Naval, and Defense alternative fuel strategies are conducted to identify similarities, differences, potential solutions, and military implications. The challenges associated with implementing the published fuel strategies from a technological risk, suitability, and affordability perspective will be examined, with emphasis on existing approaches to renewable fuels. Finally, this study will then make recommendations for changes in order to meet the DoD's aviation fuel objectives.

Delimitations

Since the Air Force and Naval aviation account for the largest energy consumption within the DoD, this study will focus on the strategies of these services as they pertain to meeting larger goals and objectives. Other Defense agency contributions, such as those from DARPA and DLA, are included for foundational reference, but their specific contributions are not directly assessed in this study's analysis. While Army aviation accounts for significant percentages of the Service's fuel consumption and budget, the Air Force and Naval operational energy strategies are better suited for evaluation and comparison for the larger purpose of this study. Furthermore, the US Army has yet to publish a formal strategy and goals for alternative fuels for its tactical vehicles.

Significance of Thesis

Fuel reduction and alternatives have proven vital in light of recent economic downturns and US military operations worldwide. Budgets affect capabilities which, in turn, influence the formulation of policy and strategy. This study focuses on the military's ability in meeting defense energy requirements within aviation operations. The historical review of Air Force and Navy efforts, comparison of the USAF and USN strategies, and evaluation of ongoing defense and industry efforts on aviation fuel diversification provides qualitative and quantitative measures of the likelihood in achieving broader US energy security objectives.

A great deal of literature has been devoted to the subject of energy security and alternative fuels, to include recently penned national and defense strategies, independent feasibility studies, as well as evaluations in journals, articles, and periodicals. This body of research will be examined in chapter 2.[34]

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[33]Ibid.

[34]Ibid., 141-215.

CHAPTER 2

LITERATURE REVIEW

A variety of sources exist on the topic of energy security, resilience, clean and renewable energy. For the purpose of this study, the available literature is divided into three categories: recent energy legislation and directed studies, published strategies, and independent evaluations and reports published in journals, articles, and periodicals. Recent legislation required the creation of a new DoD organization responsible for operational energy and the subsequent publication of an energy strategy. These legislation and strategies are presented chronologically in this study. Subsequent published studies cited the ability of these organizations to affect the necessary change required to implement new energy strategy.

Following a discussion of these three categories, this chapter briefly analyzes the literature, identifies trends, and discusses the significance of this study to the existing body of knowledge on energy security and alternative fuel strategy.

Significant Literature

Publications by new organizations and task forces within the Office of the Secretary of Defense, DLA, DARPA, as well as the individual Service components address the varying challenges of aviation fuel use as they relate institutionally. These publications exist in the form of official Defense, Air Force, and Navy Energy Strategies.

National Strategy and Legislation

The *2010 NSS* identified the need to "continue to transform our energy economy, leveraging private capital to accelerate deployment of clean energy technologies that will cut greenhouse gas emissions, improve energy efficiency, increase use of renewable and nuclear power, reduce the dependence of vehicles on oil, and diversify energy sources and suppliers."[1] It also acknowledges the nation's vulnerabilities to supply interruptions, manipulations, and extraordinary changes in the environment.[2] Finally, it warns against de-incentivizing private industry in developing new energy technologies.

Legislation that established goals and directives towards energy goals, security, and technology preceded the current NSS. The 2007 EISA identified the relationship between energy security and the increased production of biofuels. First, the EISA directed the implementation of a renewable fuel standard for domestic transportation fuel. According to this Act, renewable fuel production would occur in new facilities and achieve a 20 percent reduction in "lifecycle greenhouse gas emissions compared to certain baseline lifecycle greenhouse gas emissions."[3] In addition, Section 526 of the Act allowed the government to purchase fuels with lifecycle greenhouse gas emissions that are less than or equal to those of their petroleum-derived counterparts.[4] The Act also authorized appropriations for FY2008-FY2015 for the Secretary of Energy to establish a grant program in support of advanced biofuels production.[5]

Fiscal Year 2010 saw the first piece of legislation to directly impact the federal government and shape subsequent energy strategies. Executive Order 13514, titled *Federal Leadership in Environmental, Energy, and Economic Performance*, directed federal agencies to increase energy efficiency; measure, report, and reduce greenhouse gas emissions, and leverage agency acquisitions to foster markets for sustainable technologies.[6] While these mandates were directive in nature, they were limited in scope to government fleet vehicles.

The White House's March, 2011 *Blueprint for a Secure Energy Future* was a recent positive step towards the advancement of biofuels technology. This document outlines a three-tiered strategy for reducing foreign energy dependence while expanding clean and renewable sources.[7] The plan aims to develop and secure the nation's energy supplies, provide consumers with increased options to reduce costs and save energy, and innovate towards a clean energy future. In addition, President Obama directed the Departments of Agriculture, Energy, and Navy to work with private industry towards the development of advanced drop-in biofuels for both defense and private sector use. A subsequent memorandum of understanding signed by the respective department secretaries and the Air Force, which served as the DoD Executive Agent for the Defense Production Act Title III Program, provided a subsequent Request for Information titled *Advanced Drop-in Biofuels Production Market Research* on 29 August 2011. By definition, Title III of the *Defense Production Act of 1950* (50 U.S.C. App. § 2061 *et seq.*) grants Presidential authority to provide incentives to expand domestic production capabilities deemed essential for national security.

Defense Strategy

The impetus for DoD energy strategy was nested in the *2010 National Defense Strategy* and the *2010 Quadrennial Defense Review* (*QDR*). The *National Defense Strategy* identified DoD action to examine energy use and evaluate fuel reduction without unnecessary risk to operational capability in support of wider government and environmental objectives.[8] The *QDR* further outlined the access and protection challenges of reliable energy sources, and acknowledges the implementation of the energy Key Performance Parameter and the Fully Burdened Cost of Fuel metrics as mandated in the 2009 National Defense Authorization Act (NDAA).[9] Also mentioned in the QDR were the Department's efforts into alternative energy concepts, including the creation of an innovation fund intended to spur completion for advanced integrated energy solution projects among components.[10]

The Duncan Hunter NDAA for FY 2009 established the foundation for creation of a DoD-level entity regarding energy policy and strategy development. This act authorized the creation of a Director of Operational Energy Plans and Programs in the Office of the Assistant Secretary of Defense, with the mission of assisting combatant commands and military services in improving "military capabilities, cut costs, and lower operational and strategic risk through better energy accounting, planning, management, and innovation."[11]

The following year's NDAA called for a DoD study on renewable fuel supply and demand through 2020 in response to Section 334 of the FY2010 Act. Titled *Opportunities for DoD Use of Alternative and Renewable Fuels*, the study was a collaborative effort between the newly-created Assistant Secretary of Defense for Operational Energy Plans and Programs, the Defense Logistics Agency, and the Services. The report yielded significant findings in terms of renewable fuel projected cost and growth, increased Service demand, limited estimated industrial capacity, and the absence of jet fuel as part of the 2007 EISA mandate.[12]

The FY 2011 NDAA subsequently changed the Director of Operational Energy Plans and Programs to the Assistant Secretary of Defense for Operational Energy Plans and Programs.[13] The office unveiled its first formal strategy in 2010 titled *Energy for the Warfighter: Operational Energy Strategy*. The document outlined a broad effort to reduce defense dependence on oil while expanding its use of alternative energy sources.[14] The strategy is based on three primary objectives: more fight, less fuel; more options, less risk; and more capability, less cost**.**[15] In March, 2012, a supplemental *Operational Energy Strategy Implementation Plan* was published in accordance with a parent strategy that established specific target timelines for meeting the three main objectives. The overall intent of the plan is the formal integration of energy considerations and transformation into existing DoD plans and programs.[16]

Air Force Strategy

The USAF was the first service to pursue research, development, testing, and certification of alternative fuels. In 2010, the USAF published the *Aviation Operations Energy Plan*, an appendix to the larger *Air Force Energy Plan*, which provided the service's baseline for aviation energy goals, objectives, and metrics. The Air Force's goals were consistent with those at the defense-level, and based on three pillars: reduced demand, increased supply, and culture change.[17] The wider USAF Energy plan established various near-, mid-, and long-term milestones. Specifically, the *Aviation Operations Plan's* intent was to achieve these goals through leadership in energy management, efficient flight operations, the inculcation of energy awareness, and the maximizing of technology use for fuel efficiency.[18] In the near-term, the plan called for continued fleet-wide synthetic fuel certification using the FT process by 2011. With the exception of the MQ-9 Reaper and CV-22 Osprey, all fielded platforms were certified for unrestricted operations using the FT-derived synthetic fuel blend.[19] Additionally, the USAF has certified F-15, F-16, and C-17 aircraft to use a 50 percent biofuel blend.[20] In the mid-term, the service aims to reduce fuel consumption by 10 percent as compared to a

FY 2006 baseline by 2015. By 2016, the USAF intends to be prepared to acquire 50 percent of its aviation fuel requirement from alternative sources. By 2030, the service plans to operate aircraft on alternative fuel blends once they are cost effective, domestically produced, and have a life-cycle GHG footprint less than or equal to that of petroleum.[21]

Naval Strategy

A similar detailed plan exists for US Navy forces, titled *A Navy Energy Vision for the 21st Century*. Published in October, 2010, the strategy cited five strategic energy imperatives; of which three are aviation-fuel related.[22] The Secretary of the Navy's first goal is to demonstrate a Green Strike Group in local operations by 2016, followed by an operational deployment in 2016. By 2020, half of all Navy energy consumption will come from alternative sources. Additionally, the Navy plans to produce at least 50 percent of its shore-based energy requirements from alternative sources. Most recently, the Navy, in conjunction with DLA Energy, signed a contract for the single largest purchase of biofuels in government history in support of their ongoing efforts. The 450,000 gallon purchase of used cooking oil and algae will be used as part of a larger drop-in fuel requirement for JP-5 and F-76 during the Green Strike Group demonstration during the Rim of the Pacific Exercise in 2012.[23] This demonstration will support the more ambitious follow-on goal of sailing the Great Green Fleet in 2016, which will require an estimated 300 million gallons of biofuel and spotlight the interagency effort of the Departments of Agriculture, Energy, and Navy towards the advancement of drop-in biofuels for civil and defense use.[24]

DARPA Efforts

Perhaps the most ambitious plan for fossil fuel alternatives exists with DARPA. The agency, known for balancing high risk with high payoff technologies, seeks to demonstrate the feasibility of producing an algae-based biofuel for approximately $3 per gallon, down from its current $20-$30 price tag.[25] Three-year contracts were awarded to General Atomics and Science Applications International for meeting DARPA's price point target in 2009.

DLA-Energy

Previously cited legislation also established mandates for the DLA-Energy, the DoD Executive Agent for bulk petroleum. The mission of DLA-Energy is to provide effective, efficient, and comprehensive energy solutions to the DoD and other government agencies. The 2009 NDAA tasked DLA Energy to conduct an analysis of renewable fuel capability to meet DoD mobility fuel requirements.[26] According to the recent *DLA Energy Fact Book*, the agency has continued Hydrotreated Renewable Jet (HRJ) 5 and HRJ 8 drop-in bio fuel replacements for JP 5 and JP 8 used by the Navy and Air Force, respectively, in line with their individual certification efforts.[27] In addition to supporting these efforts, the agency evaluates the impact of alternative fuel technologies on handling and distribution, and develops and approves new alternative fuel specifications for biofuels.[28]

Research Reports and Studies

In 2008 the Defense Science Board Task Force issued a report examining the DoD's strategy to achieve assured energy supplies for its various missions. The report, titled *More Fight–Less Fuel*, satisfied a number of inquiries including fuel demand reduction by deployed forces; cited the impacts on cost and force structure; identified opportunities to deploy renewable and alternative energy sources; acknowledged the potential institutional barriers to change; and recognized potential benefits resulting from new energy technology deployments.[29] The Board's primary conclusion of relevance to this study was the DoD's lack of appropriate strategy, policies, metrics, and structure to address and manage its energy risks.[30] The report outlined recommendations to address these deficiencies, many of which now exist in various forms in current defense and military service strategies.

The Center for a New American Security published a 2010 study highlighting DoD's energy challenges and recommendations for a way ahead. Parthemore's and Nagl's report, *Fueling the Future Force: Preparing the Department of Defense for a Post-Petroleum Era*, concluded that the DoD needed a long-term strategy to adopt alternative fuels, and identified the strategic necessity in finding suitable petroleum alternatives over the next 30 years.[31] The authors stressed aviation fuel as the logical target for strategy focus based on its most immediate impact. They further suggested increased efforts with the national legislature to reduce existing misalignment in renewable energy incentives, and cited the overall lack of a long-term strategy as an impediment in meeting national energy goals. Finally, the study offered practical recommendations regarding organization, materiel, funding, and logistics towards implementing a feasible strategy capable of meeting the specified 30-year target.

The International Civil Aviation Organization presented the 2009 information paper *U.S. Fuel Trends Analysis and Comparison to GIACC/4-IP/1* to the Group on

International Aviation and Climate Change. The study focused on the potential for carbon dioxide emissions savings realized through various production pathways through the year 2050. In particular, GHG emissions for alternative fuels were analyzed throughout the entire fuel production process of recovery, processing, transport, and combustion.[32] The paper also correlated the effects of LUCs and the potential for increased GHG emissions that could overwhelm the benefits of carbon dioxide absorption from biofuel production. Their analysis of lifecycle GHG emissions is applied to this study's suitability evaluation.

In 2009, the RAND Corporation and the Massachusetts Institute of Technology (MIT) published the joint technical report *Near-Term Feasibility of Alternative Jet Fuels* for commercial aviation. Focusing on 2007-2017, the study investigated alternative fuel compatibility with existing aircraft and infrastructure, production potential, costs, lifecycle GHG emissions, and potential solutions based principally on North American resources.[33] This report was referenced in follow on studies by RAND and Congress regarding alternative fuel use for military applications.

RAND subsequently released a comprehensive 2011 study titled *Alternative Fuels for Military Applications* at the request of the DoD, and in response to the query outlined in the 2009 NDAA. The report credited the Service-driven approach to alternative fuels given the lack of both Congressional requirements for alternative fuel use in DoD tactical systems and similar directives from the Secretary of Defense.[34] It supported the FT fuels effort for production of coal and biomass mixtures to meet federal GHG limits as outlined in the 2007 EISA. This backing was based on carbon dioxide emissions control through CCS during production of CTL- and CBTL-based fuels, and negligible LUC effects for biomass-based fuels. RAND also highlighted the lack of governmental promotion of FT fuel for commercial use despite its promising ability to meet military and civilian needs by 2030.[35] The study was less optimistic on the near- and mid-term feasibility of hydrotreated renewable oils based on production potential and commercial viability, particularly affordability and lifecycle GHG emissions.[36] The authors also favored traditional systems which supply ready-to-use fuel into theater as opposed to replacing these logistical trains with large-scale battlefield production systems utilizing alternative feed stocks.[37] Finally, the report suggested that the most important outcome of military alternative fuel goals would be national-level benefits derived from military testing, early production, and deployment. The authors were less pessimistic regarding the military's access to traditional petroleum during times of crisis than on the government's ability to achieve significant progress towards alternative fuels without the DoD's efforts.[38]

Professional Military Studies

The US Air Force's and Navy's pursuit of alternative energy has generated a number of studies from within their own ranks. USAF Major Thomas Seymour's 2009 Air Command and Staff College research paper "Algae-Based Jet Fuel: The Renewable Alternative to the Air Force's Focus on Coal-To-Liquid Synthetic Fuel" concluded that the Air Force was unlikely to meet its 2016 alternative fuels goal. His study argued that the USAF's emphasis on the Fischer-Tropsch Coal to Liquid (CTL) process, while economically viable, was inconsistent with the 2007 EISA's ban of federal agency procurement of alternative or synthetic fuels with more lifecycle GHG emissions than petroleum-based fuels.[39] He offered an alternative focus on algal- or biomass-based jet fuels that are more likely to gain political support and is more viable in light of aggressive alternative fuel standards. In a similar effort, US Navy Lieutenant Alaina

Chambers' and Dr. Steve Yetiv's research titled "The Great Green Fleet: The U.S. Navy and Fossil Fuel Alternatives" described related naval efforts as ambitious, but attainable. The authors detailed Navy Secretary Ray Mabus's vision of energy transformation in light of the costs and technological challenges facing implementation. Furthermore, they argued that military-inspired energy efforts of the Navy and Air Force are commendable and somewhat isolated from political and civilian deadlock, accounting for most progress made to date.[40]

Analysis of Literature

Current Air Force and Navy strategies, along with think-tank recommendations, provide ends, ways, and means in meeting the stated defense energy goals. There remains, however, a lack of a national-level renewable fuel mandate or strategy for aviation fuel as highlighted in various sources. The term "energy" is used only twice in the 2010 National Military Strategy, and with no mention of alternative fuel or diversification. The FY10 NDAA Congressional Study *Opportunities for DoD Use of Alternative and Renewable Fuels* revealed that the 2007 EISA excluded jet fuel from production mandates, thus reducing private industry incentives to embark on renewable aviation fuel efforts.[41] Further, some technologies, such as the FT synthetic blends pursued heavily by the Air Force or biofuels by the Navy, have yet to be produced in large quantities with sufficient CCS or at competitive costs.

Trends

The principal trend in the existing energy strategy is the harmony of defense goals with independent recommendations. Individual Services have nested larger defense goals, but overall strategies and policies at the Joint level are lacking. The ability to achieve the various goals is, however, questionable. Additionally, each strategy is predicated on adequate economic means and technologies that are not yet fully mature. The combination of these two variables given the current environment of fiscal austerity is an alarming challenge to the feasibility of these strategies. The underlying variables that emerge regarding alternative fuels are technological feasibility, environmental suitability, and affordability.

Significance of Thesis in Relation to Existing Literature

Most recent literature on the topic of military alternative energy is related to the publishing of the DoD's Operational Energy Strategy and subsequent Service-related goals and objectives. Few studies, such as the RAND Corporation's report, have assessed the capacity for these strategies to be successful given the possibility of significantly reduced defense spending. Thus, the identification of areas for improvement within national, defense, and military strategies is imperative in a fiscally austere environment. Furthermore, the analysis presented in this study is relevant to the decisions that must be made by the Defense Operational Energy Board.

Research Analysis Literature

Qualitative analysis literature was referenced to provide a sufficient theoretical foundation in which to answer the research questions posed in this study. Research Professor John Creswell's insights into research design provided clarity on the nature of data found in existing literature. He described qualitative research as open-ended, emergent, and fundamentally interpretive.[42] According to researchers Miles and

Huberman, qualitative data are typically expressed through words, collected through a variety of means, and require a level of processing prior to presentation. Simply expressed, this process entails reduction, display, and conclusion drawing. The interactive data analysis model presented by Miles and Huberman provided a suitable conceptual framework for selecting, focusing, simplifying, and transforming qualitative data collected during the literature review.[43] This model also aligned with Creswell's iterative reasoning process, characterized by transitions between data collection and analysis to problem reformulation.[44]

Technical risk, suitability, and affordability are the three criteria that will provide the basis for this study's evaluation. These terms are defined in Chapter 3.

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[1]The White House, *National Security Strategy* (Washington, DC: Government Printing Office, 2010), 30.

[2]Ibid.

[3]Public Law 110-140, *Energy Independence and Security Act of 2007*, (Washington, DC: Government Printing Office, 2007), 202.

[4]James T. Bartis and Lawrence Van Bibber, *Alternative Fuels for Military Applications* (Santa Monica, CA: RAND Corporation, 2011), xii, http://www.rand.org/content/dam/rand/pubs/.../2011/RAND_MG969.pdf (accessed 25 April 2012).

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[6]Executive Order no. 13,514, *Federal Leadership in Environmental, Energy, and Economic Performance*, title 3, sec. 783 (2009).

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[9]Department of Defense, *Quadrennial Defense Review Report* (Washington, DC: Government Printing Office, 2010), 87.

[10]Ibid.

[11]Public Law 110-417, *Duncant Hunter National Defense Authorization Act for Fiscal Year 2009* (Washington, DC: Government Printing Office, 2008), 902.

[12]Department of Defense, *Opportunities for DoD Use of Alternative and Renewable Fuels: FY10 NDAA Section 334 Congressional Study* (Washington, DC: Government Printing Office, 2010), v.

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[19]Department of the Air Force, *United States Air Force FY 2012 Budget Overview*, 79, http://www.saffm.hq.af.mil/shared/media/document/AFD-110210-034.pdf (accessed 27 April 2012).

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[34]Bartis and Van Bibber, ix.

[35]Ibid., xii.

[36]Ibid.

[37]Ibid., xiv.

[38]Ibid., xv.

[39]Thomas P Seymour, "Algae-Based Jet Fuel: The Renewable Alternative to the Air Force's Focus on Coal-To-Liquid Synthetic Fuel" (Master's thesis, Air Command and Staff College, 2009), 18, http://www.dtic.mil/dtic/tr/fulltext/u2/a540165.pdf (accessed 27 April 2012).

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[44]Creswell, 183.

CHAPTER 3

RESEARCH METHODOLOGY

Extensive literature exists on energy security and renewable fuel for aviation use; however the current record largely fails to address the challenges of this problem from a Service- and defense-level perspective. To answer the research questions posed in chapter 1, this study incorporates a qualitative analysis approach. While some quantitative data that form the foundation of support material do exist, the inferences and subjective judgments made based on the interrelation of various factors will be dominantly subjective in nature. A brief historical review of recent military alternative fuel efforts is included to augment the ensuing analyses. This study's centerpiece is a comparative analysis made between the Air Force and Navy energy strategies' ends, ways, and means to the goals and requirements found in the 2011 DoD *Operational Energy Strategy*. A subsequent comparative analysis is made between the Services' collective efforts within the larger defense strategy and the existing policies and plans of the US Government. Technical risk, suitability, and affordability are used as evaluation criteria in each comparison, and they are defined later in this chapter. These criteria are then used to assess congruency between national and military strategies. This study then recommends changes in Chapter 5 to meet the challenge of meeting near-, mid-, and long-term energy goals in support of larger defense and national-level energy objectives. For the purpose of this study, near term is defined from the publication of the DoD and Services' strategies in 2010 to the present, mid-term is defined from 2013-2020, and long-term is defined from 2020 to 2030.

This chapter describes the data collection methodology, research criteria, feasibility of this research method, sources' material credibility, along with strengths and weaknesses of this methodology.

Data Collection Methodology

Secondary research was conducted through extensive use of national, defense, and military internet-based sources. Research librarians from the Combined Arms Research Library, Fort Leavenworth, Kansas provided an extensive collection of primary research of others in the form of publications, reports, journals, and professional military studies pertaining to this subject area. Online catalog searches were made using terms related to energy security. Bibliographies and reference lists of significant literature enabled further investigation into the subject.

Research Criteria

The contextual elements surrounding the topic of energy security and alternative fuels create a complex problem for strategy and policymakers at all levels of government. The literature review illustrates the variety of approaches taken in addressing the issue of institutional adaptation of alternative fuel strategies. The current military services' alternative fuel endeavors are more advanced and broader in scope when compared to civilian commercial efforts.[1] Thus, comparative analyses from within and between government entities, and qualitative assessments of their likelihood in meeting larger objectives, are significant for the purposes of recognizing strategy challenges, suitability, and opportunities for improvement.

Research Methodology

The primary and secondary research questions presented in Chapter 1 are addressed through: (1) a comparison of USAF and USN energy strategies; (2) review of existing national level strategies and policies; (3) comparison of defense strategy to the existing US government strategies and policies; and (4) inferences and interpretations of congruence. Recommendations for improvement of these strategies to meet DoD and National needs based on analysis of this research are made in chapter 5.

Evaluation Criteria

Technical Risk

The technical risk criterion evaluates the availability of a particular alternative fuel solution against a specified demand in a given period of time. A solution with acceptable technical risk is, or will be, available in sufficient quantity in order to meet at least 95 percent of the stated fuel demand within the prescribed time period. Moderate technical risk characterizes a solution assessed to meet between 50 and 95 percent of the projected requirement. An alternative fuel which is projected to meet less than 50 percent of the Service demand is assessed to have excessive technical risk. Service-specific fuel demands are identified in chapter 4.

Suitability

Suitability measures the ability of each approach towards adhering to environmental mandates on greenhouse gas emissions within the stated timeframe. GHG intensity analyses, conducted in 2009 by the Group on International Aviation and Climate Change and referenced in the MIT-RAND report on alternative fuel feasibility, are used to characterize the suitability of the proposed solutions. These data are presented in Appendix C. They represent lifecycle GHG emissions for various alternative fuels normalized for Jet A produced from conventional petroleum, and consider four types of LUC pathways for soy and palm oil-based HRJ.[2] These pathway scenarios are identified as S0-S3 for soy-oil and P0-P3 for palm oil, and are described in table 1.

Table 1. Land-Use-Change Scenarios Explored for Hydroprocessed Renewable Jet Fuel Pathways

Pathway	Scenario	Description
Soy oil to HRJ	S0	No land-use-change
	S1	Grassland conversion to soybean field
	S2	Worldwide conversion of non-cropland
	S3	Tropical rainforest conversion to soybean field
Palm oil to HRJ	P0	No land-use-change
	P1	Logged-over forest conversion to palm-plantation field
	P2	Tropical rainforest conversion to palm-plantation field
	P3	Peatland rainforest conversion to palm-plantation field

Source: Group on International Aviation and Climate Change, *U.S. Fuel Trends Analysis and Comparison to GIACC/4-IP/1* (International Civil Aviation Organization, 2009), Table B.2.

High, low, and baseline emissions cases are represented by uncertainty bars, and are used to assess suitability in this study. The lifecycle of a suitable alternative fuel will neither exceed lifecycle GHG emissions as compared to emissions from conventional petroleum, nor incur additional GHG penalties as the result of LUC issues from feedstock cultivation. Therefore, a suitable fuel solution is represented by an uncertainty bar within the normalized lifecycle GHG intensity of 1. An unsuitable approach is one whose uncertainty bar lower limit is greater than 1. Conversely, a very suitable approach has an upper limit emission that is less than 1. Because test fuels are exempt from meeting emissions criteria as defined in the 2007 EISA, Section 526, near-term fuels used in testing will be considered suitable.

Affordability

Affordability is used to assess the cost competitiveness of the identified approach. For the purpose of this study, a fuel price within $10 of the West Texas Intermediate[1] price of $110 per barrel is used as the benchmark for acceptable affordability when comparing the same volume of alternative and traditional petroleum fuels.[3] Fuel prices less than $100 per barrel are considered very affordable, while those in excess of $120 per barrel are considered unaffordable. This benchmark will be applied to the affordability assessment of production fuels, thus the high price of near-term test fuels are exempted from this criterion, and these fuels will be considered affordable.

[1]Crude oil refers to a mixture of hydrocarbons that exists underground in liquid form that is refined to produce a range of petroleum products such as gasoline, diesel and jet fuels, ethelene, propane, and butane. West Texas Intermediate is a domestic subset of deliverable crude oil typically characterized as Light, Sweet Crude Oil, or Cushing, Oklahoma as defined by the United States Energy Information Administration. West Texas Intermediate, Brent Crude, and Dubai/Oman are commonly used pricing references for oil.

The assessment of each strategy in relation to the three evaluation criteria will be displayed using thermo-pictographs in both comparisons. A red assessment indicates that the stated objective has excessive technical risk, is unsuitable, or unaffordable, and receives a numerical score of 1. A yellow color is a moderate assessment that indicates a solution possesses moderate risk, is suitable, or is affordable, and is scored as 2. A green assessment indicates that a solution has acceptable technical risk and will likely succeed, is very suitable, or is very affordable, and receives a score of 3. Each evaluation criterion is weighted equally and represents one-third of the total assessment during the USAF-USN comparison in Appendix A, and one-sixth of the total assessment during the military-national comparison in Appendix B.

An arithmetic average is performed to provide an overall assessment for the strategy under evaluation, and the results are graphically depicted using a thermo-pictograph, which ranges from red (1) to green (3). For example: the average score of one red (1), one green (3), and one yellow assessment (2) from each of the evaluation criteria is 2.0, which would result in an overall yellow, or moderate, assessment. The precision of non-integer results are limited to one significant number following the decimal place using rounding. Thus, an average value of 2.66 would be displayed as 2.7. Gradient-colors represent a combination of assessments in the military-national comparison. In this comparison, the arithmetic average of the Air Force and Navy assessments are presented as a single assessment for each evaluation criterion.

Strengths and Weaknesses of Methodology

Extensive and readily-available reports and studies conducted by government and private entities on defense-related efforts towards energy security and fossil fuel reduction are strengths of this research. Given the contemporary relevance of this topic, the progress made through various ways and means towards meeting governmental, defense, and military aviation energy strategies' ends are adequately communicated through various modes of media.

Weaknesses do exist in this approach. First, Army and Marine Corps energy efforts are not included. Although these efforts could provide additional insight on this topic, the prescribed length of this study does not make sufficient exploration and analysis of these efforts feasible. Second, the idea of defense energy strategy is relatively new and any recommendations made could be redundant in light of published analyses and criticism. Third, the assessment methodology uses an objective framework to clarify subjective logic in order to help arrive at explainable conclusions. Within this framework, uncertainties exist regarding GHG emission estimates and the elasticity of crude oil prices. Finally, budgetary detail, which could supply a significant quantitative insight regarding current and projected defense expenditures, is not explored in detail.

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[3]Bartis and Van Bibber, 15.

CHAPTER 4

ANALYSIS

This chapter is composed of five sections for the purpose of evaluating the Department of Defense's strategy towards alternative aviation fuel: (1) DoD strategy requirements; (2) a history of USAF and USN alternative fuel efforts over the past 15 years; (3) commonalities between the USAF and USN strategies; (4) differences between the Service strategies; and (5) assessments of the Services' and DoD's strategies.

DoD Fuel Strategy Requirements

The *Operational Energy Strategy* identified four requirements for alternative fuels. First, alternative fuels must be drop-in and compatible with existing systems and infrastructure. Second, the solution must support the expeditionary and global nature of the armed forces. Third, given the possibility of leveraging agricultural feedstock, the solution must also consider the potential of impacting food prices. Finally, the alternative fuel solution must have lifecycle GHG emissions less than or equal to petroleum. This final consideration is consistent with the sole existing piece of legislation relevant to alternative aviation fuel.

History of Military Alternative Fuel Projects

Using the RAND study as a foundation, a brief history of the separate Service efforts is required in order to better understand the commonalities and differences between USAF and Navy strategies. During the 1990s, the DoD approached the Department of Energy and its associated laboratories to explore alternative fuel solutions to meet military missions.[1] Despite having found expertise and motivation towards this area of technology, the DoE's efforts were primarily focused on hydrogen and ethanol-based fuels, which have minimal military utility in tactical vehicles. The decade's low oil prices and overall limited appetite for energy research and development ultimately resulted in termination of DoE efforts on algal- and coal-derived fuels. Left with minimal support from government and industry, the services assumed lead roles in development, testing, and certification of alternative fuel solutions beginning around 2000.

The Clean Fuel Initiative of 2005 catalyzed the modern DoD focus on alternative fuels. The goal of this initiative was to encourage domestic production of clean, high-performance fuels derived from non-petroleum sources such as coal and oil shale.[2] This initiative originated from within the Office of the Undersecretary of Defense for Acquisition, Technology, and Logistics during the tenure of Undersecretary Michael Wynne, who would later become the Secretary of the Air Force in 2005.[3] The endeavor was later renamed the Assured Fuels Initiative by his successor, John Young, to highlight the effort's relevance to defense.[4] According to RAND, despite this refocused emphasis, industry and state governments lost interest in the initiative as a result of mixed signals regarding program subsidies from the DoD. Attention to the initiative was ultimately terminated in 2007.

The perceived disinterest among industry and government spurred the Service-led initiatives in alternative fuels. The Air Force began its own efforts on fuel testing and certification under Secretary Wynne, thus signaling a shift in alternative fuel emphasis to the USAF. In addition to the B-52 flight test demonstration using a 50/50 synthetic fuel blend, the USAF went so far as to endeavor establishing a CTL production facility at Malmstrom Air Force Base, Montana.[5] While these efforts were ultimately ended due to the potential of mission-related impacts, the service subsequently initiated a $10M study in response to the 2008 Defense Appropriations Bill to study a CTL plant at Eielson Air Force Base, Alaska. The results of this study are forthcoming in 2012. Navy Secretary Ray Mabus shared an equally significant role in Naval alternative fuel programs. Mabus's tenure as the Ambassador to Saudi Arabia from 1994 to 1996 heavily influenced his views on oil and American dependence on foreign sources of energy.[6] In a broader sense, Mabus's five-point plan for 2020 would serve as direct means of meeting National Security Strategy goals of diversifying energy sources and transforming the energy economy. Nevertheless, the appointment of Wynne and Mabus as respective Air Force and Navy Secretaries significantly shaped the Service-led push towards alternative fuels.

The Air Force and Navy programs garnered attention at higher levels of government. The Energy Security Task Force of 2006 and a DoD thrust towards energy efficiency and alternative sources in 2007 precipitated the 2009 NDAA, which codified DoD-level energy efforts for the first time. The subsequent publishing of the Service strategies was, in essence, a retroactive incorporation of their respective decade-long endeavors within the DoD Operational Energy Strategy. Thus, the inherent differences in approach and philosophy between the USAF and USN can be primarily attributed to the lack of formal DoD-level oversight and synergy throughout the decade.

Commonalities of Air Force and Navy Strategies

The USAF and USN plans and efforts possess few similar near-, mid-, and long term objectives. Both Services have outlined goals for alternative fuel use in aircraft, solicited industry research projects, conducted flight tests and demonstration efforts, and exercised coordination and contracting projects with DLA-Energy for synthetic fuel purchases as described in chapter 2. The Air Force successfully achieved its short term goal of fleet-wide certification in 2011. Leveraging these efforts, the Navy established a similar goal for Navy and Marine Corps Systems.[7] Their goals, as outlined in Appendix B, show harmony with recent Defense-level objectives of "more fight, less fuel" and "more options, less risk"; however the paths taken prior to codification of their strategies were divergent.

The Services' also share similar goals regarding domestic alternative fuel integration. The Air Force's mid-term goal postures the Service to be prepared to meet half of its domestic fuel requirement by acquiring cost-competitive fuel blends that do not exceed lifecycle GHG emissions as compared to traditional petroleum. It further assumes that USAF aircraft will operate on these blends by 2030 presuming they continue to meet these suitability and affordability criteria. In a more ambitious effort, the Navy intends to deploy a Green Strike Group by 2016, thereby assuming biofuels will be available in sufficient quantities. This assumption continues throughout the Navy's long-term goal of acquiring 50 percent of its total energy consumption from alternative sources by 2020.

Strategy Differences

The first major difference between USAF and USN strategies exists in the different approaches to alternative fuel technology. The Air Force's short-term goal of fleet-wide certification was based on a 50/50 synthetic fuel blend based using the FT process. While the Air Force has recently begun initial testing of biofuel blends, they have achieved the desired short-term goal using FT fuel blends. Although the Navy has leveraged Air Force FT fuel efforts towards a certification of all Navy and Marine Corps systems on a 50/50 blend of FT and conventional fuels,[8] they have opted for a more ambitious approach in its procurement of HRJ for the Rim of the Pacific 2012 demonstration. Furthermore, the services also differ slightly in their approach to certifying fuels. While the Air Force seeks to certify FT alternative fuels throughout the entire operating envelope of each aircraft, the Navy's certification process is aimed at testing common aircraft system components rather than individual certification of all Navy and Marine Corps aircraft, and then demonstrating their effectiveness in operationally representative environments.

Differing approaches towards existing environmental mandates also exist between the strategies. Generally, the types of fuel blends used throughout the Air Force's and Navy's short-term certification programs were derived from different processes: specifically, FT synthetic blends for the Air Force and HRJ for the Navy. In both cases, neither blend met, nor were required to meet, the carbon emission requirement as outlined in Section 526 of the 2007 EISA.

The final difference between the two strategies regards external defense partnerships. While both services have mutually leveraged the commercial aviation industry, DLA-Energy and other DoD agency support for alternative fuel acquisition, testing, and development, the Navy has sought greater support from outside of the DoD. Their interagency effort with the Departments of Agriculture and Energy is commensurate with the assumption of greater risk that exists regarding alternative fuel technology, suitability, and affordability. Conversely, the Air Force has hedged against this risk through its "be prepared to" posture in terms of suitability and affordability in the mid- and long-term.

Strategy Assessments

Evaluations of the Air Force, Navy, and DoD strategies are summarized in Appendices A and B. In Appendix A, each Service strategy is divided into near-, mid-, and long-term categories in which their technical risk, suitability, and affordability are individually and subjectively evaluated using the assessment methodology described in Chapter 3. Alternative fuel requirements and goals contained in the DoD Operational Energy Strategy are also listed. National Security Strategy energy goals and provisions of the 2007 EISA and *1950 Defense Production Act* are outlined in Appendix B. The Air Force and Navy strategy assessments from Appendix A are presented as a combined DoD near-, mid, and long-term assessment in Appendix B using the same evaluation criteria.

USAF Strategy Assessment

Technical Risk

The Air Force's roadmap for meeting defense alternative fuel goals has been successful in the near-term, and has a favorable outlook for the mid- and long-term regarding technical risk. According to RAND, a FT blend produced using coal or a combination of coal-biomass provides the most promising solution in terms of commercial readiness and production potential in meeting both military and civilian demands by 2030.[9]. Given favorable industry conditions, FT fuel production capacity could reach 60,000 barrels per day (BPD) in 2015.[10] The Air Force plan to acquire 50 percent of its 2016 domestic fuel requirement is estimated to be 387 million gallons of JP-8 per year or 25,000 BPD.[11] While this alone would consume approximately 41 percent of the available FT supply, it would fully meet the Service's demands as early as the mid-term. Thus, the USAF's choice to certify its entire fleet of aircraft using FT blends postures the Service to incorporate a solution with acceptable technical risk throughout the entire strategy timeline.

Suitability

FT blends used by the Air Force have the potential to meet environment GHG mandates as shown in appendix C. Certification FT fuels derived from CTL with no CCS and Natural Gas (NG) exceed the suitability criteria described in Chapter 3; but are exempt from this criterion as test fuels. The incorporation of CCS processes increases the suitability of CTL and CBTL blends, and these methods are projected to be incorporated into large-scale production in the mid-term. Therefore, FT CTL and CBTL with sufficient capture and sequestration are suitable mid- and long-term solutions in the Air Force's strategy.

Affordability

The "be prepared to" posture of the Air Force's plan allows the Service to acquire alternative fuel when prices are permissive. Economies of scale are required in order for alternative fuel blends to be considered affordable for the entire DoD. Aside from research and development efforts, it is unlikely that any one Service would be exempt from cost competitively acquiring alternative fuel. RAND estimated that coal-derived FT fuels would be competitive between \$60 and \$70 per barrel, dropping to \$50 per barrel as production experience increases.[12] Adding an estimated additional \$5 to \$7 per barrel in CCS costs maintains a level of affordability for CTL fuels as compared to the average crude oil between 2005 and 2012 of \$76 per barrel as shown in figure 2. RAND also estimated that a CBTL blend of 60/40 coal/biomass to liquid with CCS would be competitive at $105 per barrel, and therefore affordable using this study's criterion.[13]

Anticipating the availability of FT fuels in the future allows the Air Force to focus on developing flexible procurement mechanisms that would offset higher alternative fuel prices, such as those of CBTL or HRJ, until economies of scale could be realized. For these reasons, the USAF's approach to acquiring FT CTL blends is assessed to be very affordable throughout the mid- and long-term.

USN Strategy Assessment

Technical Risk

The Navy has accepted greater near-term technical risk in its decision to acquire and test HRJ fuels to blend with JP-5. F/A-18 test flights with biofuels have been matched by successful demonstrations by commercial airlines, indicating that biofuels are a viable technological solution for short-term proofs of concept. The Navy's contract for 450,000 gallons of algal and waste oil biofuels, of which 200,000 gallons will be blended with JP-5, represents approximately half of its planned biofuel requirement for the 2012 demonstration.[14] It is unclear if the existing contracted quantity of fuel could completely meet the Navy's local demonstration goals; thus there is moderate technical risk in the near-term should the planned balance of biofuel fail to be contracted.

The availability of biofuels for meeting the 2016 demonstration requirement of 660,000 gallons, or 15,700 barrels, is less questionable. This quantity represents approximately 43 percent of the current 100 BPD capacity for camelina and jatropha combined.[15] Although this demand accounts for a significant percentage of the projected supply, it fully meets the Navy's mid-term demonstration goal requirements, and, therefore, is an acceptable solution with regards to technical risk.

Navy partnerships with the Departments of Agriculture and Energy mitigate concerns regarding the long-term availability of biofuels. Prior to the announcement of this collaboration, RAND assessed that oils-based HRJ fuels were unlikely to exceed 20,000 BPD by 2020.[16] Despite this outlook, production estimates are expected to meet the Navy's estimated biofuel consumption of 4,300 BPD, or approximately 20 percent of the forecasted HRJ daily industrial capacity. Given this projection, the Navy's long-term plan to use HRJ is assessed as acceptable for technical risk.

<u>Suitability</u>

Greenhouse gas emissions and land-use-changes raise issues that complicate the suitability of a biofuel-based approach for the Navy. RAND assessed large-scale biofuel testing as premature given the inability to produce sufficient feed stocks without exceeding lifecycle GHG emissions. Despite this issue of suitability, the Navy, like the Air Force, would be allowed to acquire these biofuels for their near- and mid-term demonstrations under the auspices of test and development in accordance with the 2007 EISA, Section 526. Therefore, the Navy's choice of algal and used cooking oils[2] is deemed suitable in terms of this evaluation in the near-and mid-terms. A long-term algae-based solution for the Navy would be similarly suitable due to its potential for reduced GHG emissions from both lifecycle and land-use-change.

[2]GHG emissions from the production of used cooking and animal oils are not considered in this evaluation as they are produced for the sole purpose of combustion.

Affordability

The ambitious nature and associated technical risk of a biofuel approach further exacerbates affordability issues for the Navy. The Navy's purchase of 450,000 gallons of biofuels at a price of $26.75 per gallon in support of its 2012 local fleet demonstration has drawn criticism in Congress in light of fleet reductions proposed by the Service to meet future defense spending targets.[17] While higher costs associated with small-scale acquisition of test articles are to be expected in the near-term, the cost of the mid-and long-term approaches will grow considerably. In order for the Navy's plan to be affordable, biofuel prices would need to be reduced by at least 250 percent based on the $26.75 price per gallon contracted for in 2011. RAND assessed the affordability of hydrotreated renewable oils derived from feed stocks such as algal- and camelina-based fuels as highly uncertain in the near- and mid-term.[18] Given RAND's estimates of at least 20 years before algae-derived fuels have a significant commercial role, these economies of scale are too unlikely to be achieved, thus making the Navy's approach unaffordable in the mid- and long-term.[19]

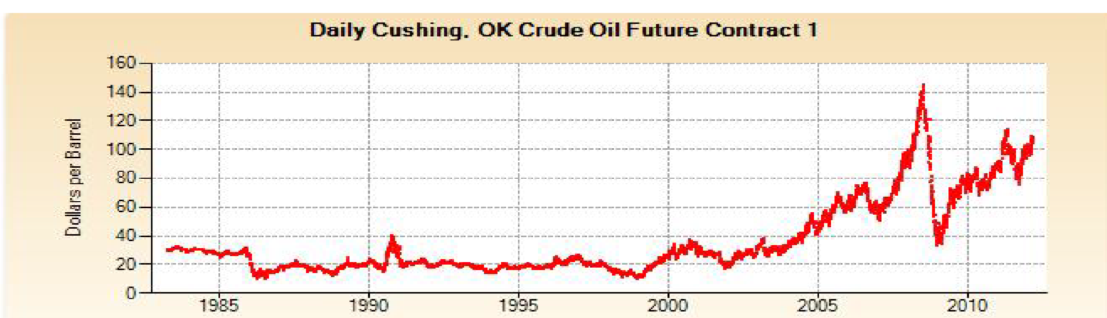

Figure 2. Daily Crude Oil Prices 4 April 1983 to 9 March 2012

Source: US Energy Information Administration, Daily Crude Prices, http://www.eia.gov/dnav/pet/hist/LeafHandler.ashx?n=PET&s=RWTC&f=D (accessed 9 March 2012).

DoD- Strategy Assessment

Service-led projects constitute the majority of the DoD strategy's ways and means, and thus provide the basis for the assessment results depicted in Appendix C. This chart illustrates the combined Navy and Air Force assessment results for each evaluation criterion. The DoD has enjoyed near-term success based on the independent and collaborative efforts of the Services with support from DLA-Energy, the Departments of Energy and Agriculture, DARPA, and the commercial aviation industry. These interagency efforts have translated into near-term certifications of alternative fuel solutions with acceptable technological risk and suitable GHG characteristics throughout the evaluation period.

However, technological and suitability gains are complicated by affordability challenges in the mid- and long-term. Poor convergence at the DoD-level has resulted in the pursuit of separate alternative fuel paths by the USAF and USN. Specifically, the Navy's biofuels-based means limits the overall strategy's affordability. Moreover, this affordability challenge will likely be exacerbated as the Department balances operational, sustainment, and modernization demands with budgetary reductions.

National-level mandates also play essential roles towards achieving the DoD's desired ends. Although the 2007 EISA and the 1950 Defense Production Act establish favorable conditions for the creation of alternative fuels with both acceptable technical risk and environmental suitability, the exclusion of jet fuel mandates has limited production estimates that directly impact renewable fuel affordability during the timeframe investigated in this study.

The March, 2012 publication of the *Defense Operational Energy Strategy Implementation Plan* provides discrete periods for assessment and adjustment, beginning with the Defense Operational Energy Board that will take place in the second quarter of FY 2012. The creation of this board was a significant step towards improving the incongruences between the Services' approaches while identifying technical and fiscal impediments towards success in the mid- and long-term. This board will provide recommendations and establish the first common framework to guide alternative fuel decisions based on maximizing national or military benefit and managing technical and financial risk.[20]

Analysis Summary

The analyses presented in this chapter reveal a history of parallel in time, yet divergent in approach, Service efforts that have also presented challenges at the DoD-level. The absence of alternative aviation fuel support within national-level legislation has constrained industrial development and stymied support for fully achieving defense goals in the mid- and long-term. The creation of the Defense Operational Energy Board was a critical step towards harmonizing DoD alternative fuel programs and providing a common vector for the Services and subordinate agencies. The next chapter will provide conclusions and recommendations for improving the DoD's position on alternative aviation fuel.

[1] James T. Bartis and Lawrence Van Bibber, *Alternative Fuels for Military Applications* (Santa Monica, CA: RAND Corporation, 2011), 52, http://www.rand.org /content/dam/rand/pubs/.../2011/RAND_MG969.pdf (accessed 25 April 2012).

[2]Timothy Bradner, "Alternative Fuels Push to Benefit Alaska," *Alaska Journal of Commerce*, 7 June 2005, http://www.enn.com/top_stories/article/16192 (accessed 27 April 2012).

[3]Bartis and Van Bibber, 68.

[4]Ibid.

[5]Stefan Milkowsi, "USAF considers Coal-to-liquids," *Petroleum News* 15, no. 5 (2010), http://www.petroleumnews.com/pnads/912589609.shtml (accessed 27 April 2012).

[6]Jim Lane, "Aviation and Military Biofuels: New Thinking on Finance and Fuels," *Biofuels Digest*, 8 February 2012, http://www.biofuelsdigest.com/bdigest/2012/02/08/aviation-and-military-biofuels-new-thinking-on-finance-fuels/ (accessed 27 April 2012).

[7]Bartis and Van Bibber, 69.

[8]Ibid., 58.

[9]Ibid., xii.

[10]Ibid., 73.

[11]Department of Defense, *Operational Energy Implementation Plan* (Washington, DC: Government Printing Office, 2012), 17.

[12]Bartis and Van Bibber, 12.

[13]Ibid., 24.

[14]Department of Defense, *Operational Energy Implementation Plan*, 17.

[15]Bartis and Van Bibber, 77.

[16]Ibid., xvii.

[17]Austin Wright, "Navy powers up campaign for great green fleet," *Politico*, 7 March 2012, http://www.politico.com/news/stories/0312/73752.html (accessed 27 April 2012).

[18]Bartis and Van Bibber., xii.

[19]Ibid., 79.

[20]Department of Defense, *Operational Energy Implementation Plan*, 18.

CHAPTER 5

CONCLUSIONS AND RECOMMENDATIONS

Conclusions

This study's analysis concludes that alternative fuel blends have the potential to offer technically feasible, suitable, and affordable solutions for the DoD by 2030. Additionally, the analysis indicates that the three criteria investigated should be considered collectively when evaluating the strategies' ability to arrive at the desired end state. Divergence and duplication among service-led programs to date has hindered achievement of the alternative fuel goals outlined in the DoD *Operational Energy Strategy*. With this plan, the DoD is poised to provide the unity of effort necessary to achieve national, defense, and military goals for the first time since the inception of these efforts. The subsequent establishment of the Defense Operational Energy Board is both timely and relevant on the eve of $500 billion in defense spending reductions and the possibility of additional cuts through sequestration. In light of these challenges, this chapter will present recommendations on how the DoD can better fulfill its stated objectives as well as areas for additional research.

Recommendations

Policy

The DoD should implement a department-wide alternative fuel policy. The policy's first objective should seek the development of common service goals, and would require the appropriate Joint oversight for Air Force and Navy programs. The Defense Operational Energy Board designated this responsibility to the Joint Staff Director of

Logistics, J-4, in March 2012. A DoD-wide policy would also provide consolidated alternative fuels management, which will be essential during the pending budgetary reductions.[1] Furthermore, service-aligned goals would assist DoD leaders in synchronizing mid- and long-term certification targets within the Planning, Programming, Budget, and Execution, Joint Capabilities Integration Development System, and Acquisition processes.

Emerging DoD alternative fuel policy should focus on achieving initial operational capability using a single, available solution that is both suitable and affordable. A single solution would allow leveraging among the Services' budgets for fuel purchases and follow-on testing, simplify DLA-Energy's acquisition and logistics footprint required for an alternative fuel, and demonstrate a common DoD commitment to the commercial aviation and energy industries. Ultimately, the capability to provide global support for alternative fuel acquisition will reside with DLA-Energy, and is outside the scope of the Services' Title 10 responsibilities. But when realized, these opportunities could satisfy a DoD alternative fuel requirement for supporting the deployed expeditionary force assuming these sources adopt similar GHG mandates as the United States.

Defense policy alone cannot solve the dilemma of achieving national level energy objectives. Renewable fuel mandates must be included in new energy legislation to invigorate industry growth in alternative fuel. A domestic commitment could inspire similar incentives abroad, and increase the availability of alternative fuels for expeditionary forces. The successes achieved in gasoline fuel reduction resulting from higher efficiency vehicles and alternative blends serves as a testament to the benefit of federal energy mandates.

Technology

Fischer-Tropsch coal-to-liquid or coal/biomass-to-liquid blends with CCS appear to offer the best possible solution for an alternative fuel when technical risk, suitability, and affordability are considered collectively. CTL fuel blends have been tested by both the Air Force and Navy, have been certified for commercial use, have the ability to meet EISA environmental requirements through carbon capture or sequestration, and have the potential to be produced and acquired affordably. Hydrotreated renewable fuel blends, while promising, are not yet mature, or available in affordable quantities to continue pursuing operational integration within the next 20 years.

Recommendations for Further Study

Greater energy security requires a stronger commitment to domestic energy exploration. Natural gas and oil exploration within the United States has grown significantly over the past decade. These abundant energy sources offer possible solutions for future drop-in fuel blends, and should be further investigated for greater use in military and commercial aviation.

The results of the Air Force's multi-year study on a CTL plant at Eielson Air Force Base are due to be released in 2012. Given the potential for high cost of this project, additional research into the possibility of a joint or interagency approach to this endeavor is appropriate considering the planned DoD budget reductions.

Affordability concerns surrounding the Navy's 2016 Great Green Fleet suggest the possibility for additional research of large scale biofuel demonstrations. Biofuel price projections that reflect recent interagency focus should be considered as they become available. Additionally, differences between the objectives of the 2012 local demonstration and the 2016 deployment should be investigated in terms of what the latter will actually accomplish other than to prove that it can be done as long as cost is no object.

Conclusion

DoD and Service energy strategies have the potential meet their stated objectives by incorporating domestic alternative aviation fuels once adequate production conditions are established and economies of scale realized. Perhaps the most important outcome of the DoD's efforts over the past decade is a reinvigorated interest at the national level for viable petroleum alternatives for aviation. Renewable jet fuel mandates, when combined with continued research, development, and testing by the military, are essential in meeting defense and national objectives.

Greening the mixture requires more than just alternative sources. Technical risk, suitability, and affordability are mutually dependent characteristics for successful implementation of an alternative fuel blend. Only a cohesive, integrated strategy that leverages technology, industry, economics, and legislation can fully meet the nation's energy horizons.

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[1] James T. Bartis and Lawrence Van Bibber, *Alternative Fuels for Military Applications* (Santa Monica, CA: RAND Corporation, 2011), 86, http://www.rand.org /content/dam/rand/pubs/.../2011/RAND_MG969.pdf (accessed 25 April 2012).

APPENDIX A

Comparison of Service Alternative Aviation Fuel Strategies

Department of Defense

Goals
- More fight less fuel
- More options, less risk
- More capability, less cost

Fuel Requirements
- Drop-in fuels compatible with systems and infrastructure
- Fuels must support expeditionary, globally deployed forces
- Consideration taken on potential food price impacts
- Lifecycle greenhouse gas emmissions less than or equal to petroleum

US Air Force

Goals
- Reduce Demand
- Increase Supply
- Culture Change

US Navy

Goals
- Assure mobility and protect critical infrastructure
- Early testing and adoption of viable alternative energy
- Lighten the load and Expand Tactical Reach
- Green the footprint

	US Air Force			US Navy		
	Near	Mid	Long	Near	Mid	Long
	1. Procure commerically produced alternative energy 2. By 2011, test/certify all aircraft and systems against 50/50 alternative fuel blend by 2011 3. By 2012 certify fleet using HRJ biofuel blend	1. By 2015, reduce consumption by 10% against a FY2006 baseline 2. By 2015, be prepared to cost competitvely acquire 50% of USAF's domestic aviation fuel requirement via alternative fuel blend from domestic sources that are greener than conventional petroleum	By 2030, aircraft are flying on alternative fuel blends if cost competitive, domestically produced, and have a lifecycle greenhouse gas footprint less than or equal to petroleum	Demonstrate shipboard demonstration of 50/50 fuel blend during RIMPAC 2012	By 2016, sail Great Green Fleet using hybrid electric ships and aircraft running biofuel	By 2020, 50% of navy's total energy consumption will come from alternative sources
Criteria						
Technical Risk	3	3	3	2	3	3
Suitable	2	2	2	2	2	2
Affordable	2	3	3	2	1	1
Overall:	2.3	2.7	2.7	2.0	2.0	2.0

Source: Created by author, data adapted from the DoD *Operational Energy Strategy*, *Air Force Energy Plan*, and *A Navy Energy Vision for the 21st Century*.

APPENDIX B

Assessment of National Mandates and Defense Fuel Strategy

National Security Strategy

Goals

- *Transform the energy economy*
- *Leverage private capital to accelerate deployment of clean energy technologies to:*
  - *Cut greenhouse gasses*
  - *Increase renewable power*
  - *Diversify energy sources and suppliers*

Energy Independance and Security Act of 2007, Sec 526

Provision

No Federal Agency shall contract for procurement of alternative or synthetic fuel, other than for research or testing, unless the contract specifies that the lifecycle greenhouse gas emissions associated associated with the production and combustion of the fuel, be less than or equal to such emissions from the equivalent conventional fuel produced from conventional petroleum sources.

DoD Actions:

1. Air Force prepared to acquire in line with EISA based on cost and availability
2. Navy committed to purchase biofuels with no consideration of cost or environmental restriction
3. DLA-Energy support to ongoing Service testing

Defense Production Act of 1950

Provision

The DPA authorizes the President and Congress to directly invest in the commercialization of vital defense technologies that would otherwise not reach (or too slowly reach) commercial-scale production at affordable prices. To ensure that a commercial market for advanced biofuels developed, the US Government recently invoked the Defense Production Act of 1950, issuing a presidential finding the advanced biofuels were total to national security.

DoD Actions:

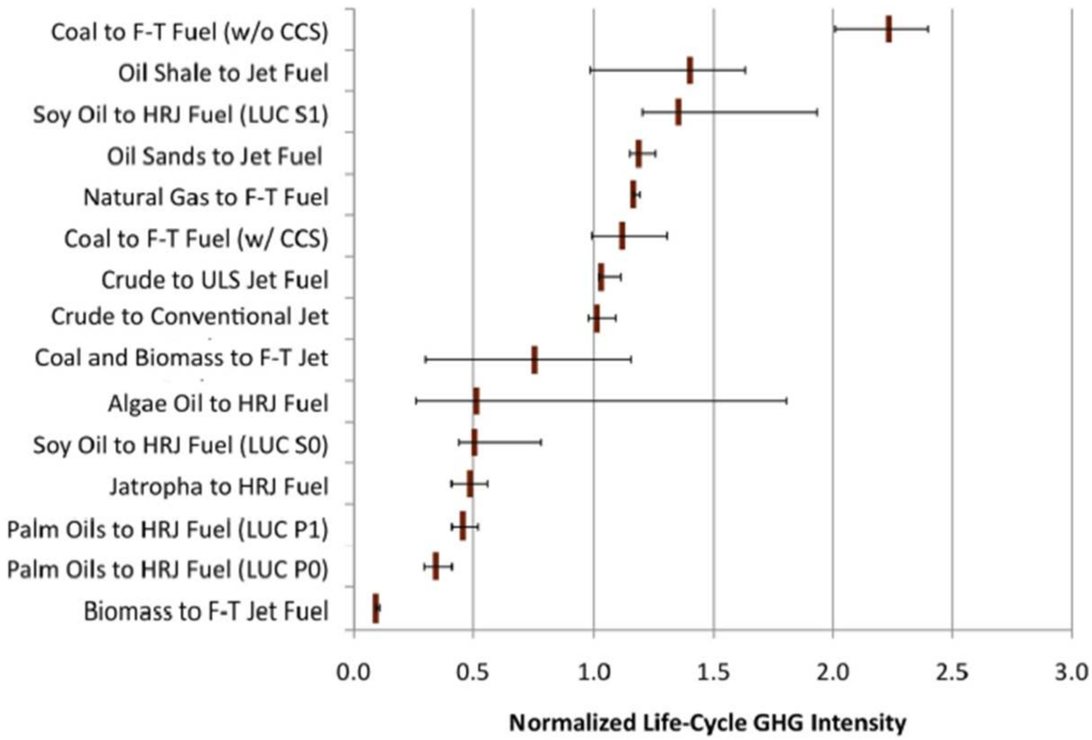
1. DOE, USDA and the US Navy jointly announced each branch of government's committment of $170 million in previously authorized funding towards the commercialization of advanced biofuels
2. Private sector contributions are expected to be matched 1:1, providing $1B towards the effort
3. DARPA advanced biofuel program
4. DLA Energy alternative fuel acquisition support

Criteria	Near	Mid	Long
Technical Risk	2.5	3.0	3.0
Suitable	2.0	2.0	2.0
Acceptable	2.0	2.0	2.0
Overall:	2.2	2.3	2.3

Source: Created by author, data adapted from the DoD *Operational Energy Strategy*, *Air Force Energy Plan*, *A Navy Energy Vision for the 21s[t] Century*, Energy Independence and Security Act of 2007, Defense Production Act of 1950, and the 2010 *National Security Strategy*.

APPENDIX C

Normalized Lifecycle Greenhouse Gas Emissions For Jet Fuel Pathways



Source: Group on International Aviation and Climate Change, *U.S. Fuel Trends Analysis and Comparison to GIACC/4-IP/1* (International Civil Aviation Organization, 2009), Figure B.18.

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